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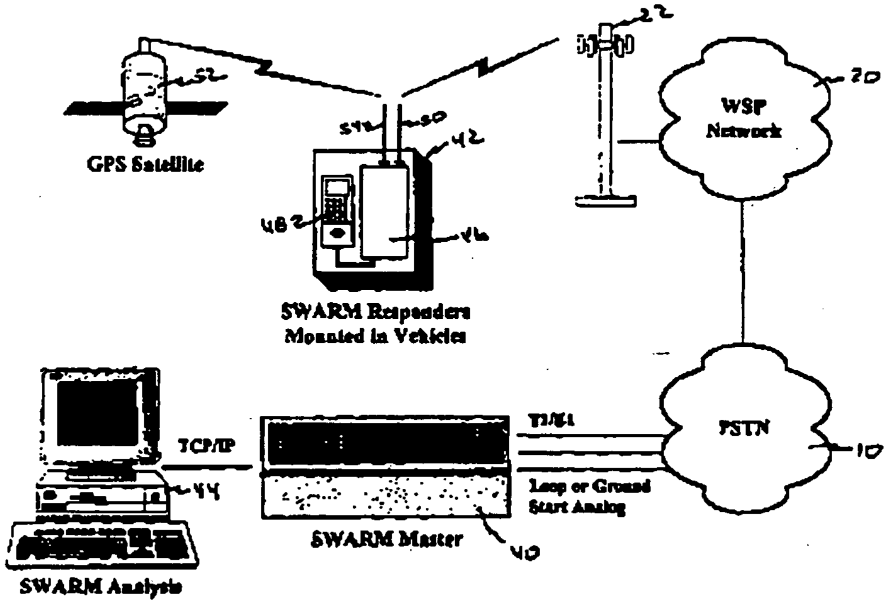

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APPARATUS AND METHODS FOR AUTOMATED TESTING OF WIRELESS COMMUNICATIONS SYSTEMS

AMERITEC CORPORATION
Inventor(s): WATSON, John, R. ; HOLLFELDER, Thomas, A.

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Abstract: Apparatus and methods are provided for testing a wireless service provider network through a virtual subscriber system. In one aspect of this invention, a method for testing a wireless service provider network generally comprises the steps of initiating outbound call attempts under control of a master to multiple automatic, mobile responders, receiving calls at at least some of the responders, monitoring parameters relating to the wireless service provider network and transmitting information indicative of those parameters to the master. Parameters testable through the system include **audio** (^) quality testing, including 23-tone testing, quantitative testing of **audio** (^) quality, RF power testing, frequency testing and spectrum analysis testing. In the preferred method, testing may be performed by multiple responder units displaced throughout the geography of the wireless service provider, so as to

network 10 and the wireless service provider 20, as well as communication links 28 among the various components of the wireless service provider network 20, are typically **digital** (^) land- based or microwave carrier systems. For example, TI, T3 or SONET facilities may be utilized.

The particular system architecture within a given wireless service provider network currently tend to be manufacturer specific. Current manufacturers of such systems include Motorola, LM Ericsson, Nortel, Hughes Network Systems, Astronet and Lucent Technologies. Mobile phones 32 are available from many commercial sources.

Historically, mobile phones 32 were analog systems. More recently, mobile phones 32 include dual-mode mobile phones which support both analog and **digital** (^) transmission systems. In addition to the providers of the wireless service network equipment, identified previously, current mobile phone manufacturers also include Oki, Samsung, Toshiba and NEC.

Cell sites 22 are geographically distributed throughout a region served by a given wireless service provider. As the cell site 22 has a limited geographic coverage area, wireless service providers have been required to determine service area coverage through various methods. Predictive models of coverage area have been utilized. Further, "drive tests" have been utilized in which a technician affiliated with the wireless service provider moves about the geography of the region covered by the wireless service provider. Typically, a skilled field engineer drives a vehicle including sophisticated **test** (^) equipment throughout the region believed to be covered by the wireless service provider. Commonly, the testing is initiated by causing a call to be placed from the mobile **test** (^) equipment to a land- based, receiving location. A communication path is thereby established between the mobile **test** (^) equipment and the receiving station. The initiation of the call from the mobile **test** (^) equipment is initiated by the technician. Tests typically performed include detailed radio frequency and system performance **test** (^) data measuring radio frequency strength, frequency, noise, co-channel interference as well as other relevant parameters. Usually, the **test** (^) data is collected and archived within the mobile **test** (^) vehicle. The **test** (^) data collected by the mobile unit is then often times combined with data from multiple other mobile units upon their return to the land- based facility.

Such "drive tests" utilizing dedicated testing vehicles is subject to a number of disadvantages. First, the testing for the entire wireless service provider network is not made in real time, as the **test** (^) data resides in multiple vehicles, not at a central site. Second, the costs associated with such dedicated vehicles is very high. A fully equipped vehicle used in a drive **test** (^) often costs from $100,000 to $250,000. Further, a skilled field engineer is required to operate the equipment and conduct the tests. Generally, multiple tasks must be performed in operating such systems, for example, the field engineer often collects the data, whereas then that data must be entered by yet another person for processing, and later for display. Yet further intervention is required for modifications or upgrading of the equipment such as for upgrading software through revisions, bug-fixes or feature additions.

Yet another type of testing performed on wireless service provider networks are cell simulation. The term call simulator has many synonyms, including, but not limited to, load tester, load box, line simulator and bulk call generator. All of these terms generally relate to devices which serve to simulate calls. Typically, a call simulator serves to automatically generate outbound calls through the wireless service provider network to various intended called parties. Typically, the called parties are individuals having a mobile phone. Various information regarding the placement of calls, such as number of attempts and call completion percentages, may be generated at the load box end of the system.

phones used in the responder architecture may alternatively be VLSI-chip-level mobile phones, **test** (^) phone or any combination thereof. A responder control system typically includes a wireless control device controller, parametric testing systems and **digital** (^) signal processing capability. Preferably, the system is equipped with a global positioning system which provides some or all of the position, time and velocity of the responder unit.

In yet another aspect of this invention, apparatus and method are provided for testing communications between a first wireless communication device and a second wireless communication device over a wireless service provider network. Generally, the apparatus and steps comprise utilizing a master to initiate a call to a first responder including a first wireless communication device, wherein the first responder is instructed to effectuate a subsequent call to the second wireless communication device in the second responder. Once the call is placed between the first wireless communication device and second wireless communication device, testing is performed. At least one of the first and second responders communicates with the master to provide **test** (^) data regarding the call between the first wireless communication device and the second wireless communication device.

In one aspect of this invention, a testing system is provided whereby "virtual subscribers" are provided by automated, mobile responder units. In the preferred embodiment, the responders are of sufficiently small size so as to readily fit within a typical automobile trunk, and are more particularly preferred to be substantially smaller than the volume of the trunk, preferably less than one cubic foot. In this way, the responders may be placed in vehicles which are not dedicated to the testing function, but have a independent purpose. For example, responders may be included in vehicles that cover regular, thorough routes, such as postal or public transit vehicles, or in vehicles which cover relatively regular routes with some degree of variation, such as delivery vehicles, or in vehicles which cover random routes, and may go into and out of the service area, such as taxis, or vehicles owned by the wireless service provider. While the responders typically would be located within a mobile vehicle, at least certain of the responders within a system may be immobile without varying from the invention described herein.

In yet another aspect of this invention, the system may be utilized to emulate any feature or function of the wireless service provider and to **test** (^) implementation of that feature.

By way of example, certain systems permit a mobile **telephone** (^) number to be changed to another area code. Certain models permit mobile phones **telephone** (^) numbers to be changed remotely. The system of this invention would permit the changing of the **telephone** (^) number of the mobile phone, when permitted, either locally at the responder or remotely, to permit testing of this feature. In this way, accuracy of roaming and number verification systems can be achieved. This particular **test** (^) would serve to verify the home location register (HLR) used by wireless service providers. Yet other features of such a **test** (^) system would permit testing of an authentication system center (AUC) which manages the security data for subscriber authentication. Similarly, the equipment identify register (EIR) which stores the data of mobile equipment (ME) or ME-related data.

Accordingly, it is an object of this invention to provide an improved apparatus and method for providing usable system quality and performance data.

It is yet another object of this invention to provide an apparatus and system which provides information regarding a wireless network without requiring drive tests by skilled is field engineers.

It is yet a further object of this invention to provide a system which serves to improve the quality and

In the preferred embodiment of the subscriber wireless automated remote measuring system, the responder 42 is capable of providing geographic position information. Most preferably, the responder 42 provides geographic position information through use of the global positioning system. In such a global positioning system, a satellite 52 provides positional information to the responder 42 as received by antenna 54. The responder 42 preferably provides the positional information via antenna 50 during a telephonic communication between the responder 42 and the line simulator 40 and analyzer 44.

In operation, the responder 42 may be deployed to various geographic locations.

In the preferred mode, the responder 42 would be included within a vehicle so as to travel through the service area. Automated coverage testing may be achieved through the use of such mobile responder units. In the preferred embodiment, the responder units 42 operate remotely under control of the master 40. Most preferably, numerous responders 42 are provided in separate vehicles or locations throughout the service area, preferably in separate vehicles, so as to provide data to the master 40 and analyzer 44 under remote control from the master 40.

In one main intended application, this **test** (^) methodology and equipment enables the wireless service provider the ability to validate service area predictive model data and to provide a survey of the quality of service and network status throughout a designated service area utilizing the wireless service providers subscriber's mobile phones. While the system may be utilized to **test** (^) for any telephony related problem consistent with the goals and objects of this invention, the main types of problems contemplated are as follows. First, unsuccessful network access may be monitored. Such an unsuccessful network access is an is uplink problem wherein the wireless subscriber is unable to originate calls from a mobile phone. Secondly, the system may check for **audio** (^) quality. Typically, simulation of voice conversation is performed over a wireless connection and measured from the wireless subscribers location. Both downlink call simulation and uplink call simulation may be tested. Third, unsuccessful call completion may be monitored. An unsuccessful call is defined as any call, either uplink and/or downlink, not completed as dialed. Fourth, dropped calls may be monitored. This generally is defined as any call terminated before a call termination command is initiated by either the calling or called party. Ciffietally, the responder 42 is preferably located within a vehicle, most preferably a vehicle which moves through a relatively large geographic area within the wireless service provider region. Examples of vehicles preferably utilized with the methods of the system include:

postal or public transit vehicles (such as those that cover regular, thorough routes), delivery vehicles (such as those that cover regular routes which vary somewhat), taxis or other wireless service provider vehicles (such as those which cover random routes and sometimes go into and out of the service area). Alternatively, the responder 42 may be placed at a fixed location.

Fig. 3 shows a flowchart for the subscriber wireless automated remote measurement system analysis methods. The master 60 bi-directionally interfaces with a graphical user interface system 62, such as the FeatureCallTM system. The master 60 accesses the **test** (^) processor 64. The **test** (^) processor 64 in turn interacts with the database 66. The database 66 bi-directionally accesses a configuration screen and data manager 68 various reports 70, standard and custom, may be prepared. Generally, the subscriber wireless automated remote measuring system analysis consists of the **test** (^) processor 64, database 66, configuration screen and data manager 68 and report generator 70.

The database 66 must be of sufficient capacity, speed and sophistication to achieve the goals and

satellite daughter board standoffs.

In yet another aspect of this invention, the combination of a standard subscriber mobile phone and a component or chip-level mobile phone may be utilized on-line simultaneously on two separate **cellular** (^) or PCS calls. The results of these two separate calls may be coordinated and correlated by the analysis system.

The first compartment 94, when adapted for holding the mobile phone, preferably includes foam rubber material on both the base 82 and the lid 84. This foam rubber material serves to receive the mobile phone 48 within a nest so as to support the mobile phone 48 during vehicle motion. Optionally, a mobile phone window 102 is provided in the lid 84 to permit user observation of the mobile phone 48 panel.

The second compartment 96 is connected to the first compartment 94 by a connector 5 104 passing through shield 92. The mobile phone connector 106 meets with connector 104 and connects to the mobile phone 48. The mobile phone connector 106 is typically unique depending upon the type of mobile phone 48 utilized. The software utilized by the responders **cellular telephone** (^) controller serves to configure the system for the specific brand of mobile **telephone** (^) then utilized within the responder 80.

The responder 80 includes various connections to external. An antenna connection 108 and global positioning satellite antenna connector 110 are provided. A barrier strip 112 or water tight connector preferably provides for connection to ground 114, battery 116 and vehicle ignition 118. Preferably, provision is made to reduce risk of electrical error from electrostatic discharge through use of O-rings or elastomeric gaskets for sealing.

Fig. 5 shows an electrical block diagram of the responder electronics. A microprocessor 110, such as Zilog microprocessor, is coupled to an address bus 112, databus 114 and control signal lines 116. A power supply 118 provides power to the system, and preferably comprises the vehicle battery. A regulator/sensor 120 provides a low battery voltage flag signal to the microprocessor 110 via the address but 112. The regulator 120 optionally couples to a mobile phone variable voltage regulator 122, which in turn is connected to the mobile phone input/output port 124. The mobile phone input/output port 124 is preferably coupled to an analog to **digital** (^) codec 126 providing phone/**audio** (^) input/output. The A/D codec 126 is coupled to buses, such as address bus 112 and databus 114. Preferably, the A/D codec 126 is coupled to a **digital** (^) signal processing chip 128, such as a 2171 DSP chip. The mobile phone input/output port 124 is further connected for mobile phone data and control signal communication to the mobile phone controller 130. The mobile **telephone** (^) 130 is coupled to the buses, such as the address bus 112 and databus 114. External computer input/output 132 is likewise coupled to the buses.

Various control signals 134 are provided to various electronics. Chip select is effected via coupling between the address bus 112 and the control signal interface 134.

Optionally, an electronically programmable logic device (EPLD) 136 connects the chip select and control signal interface 134.

Optionally, a global positioning satellite system is utilized. A GPS daughter board 136 is coupled to the database 114. An antenna 138 connects to the daughter board 136.

Fig. 6 is a software flowchart for the responder program flow. At start- up 140, cold start begins when

is done with the command at block 248.

Fig. 11 is a flowchart for the 23-tone **test** (^) receiving and scoring sequence. The 23- tone **test** (^) is described in one or more of the following United States Patents No. 4,301,536, 4,417,337 and 4,768,203, incorporated herein by reference. The master establishes the call at block 250, acquires **digital** (^) signal processing (DSP) resource at block 252 and transmits a prompting command at block 56 to the responder. The responder begins in a wait state 256, and receives the command from state 254 at the responder side in state 258. While the master waits a period of time, e.g., 500 milliseconds at block 260, the responder during that wait interval 260 prepares a DSP to receive the 23-tone sequence at block 262. The master sends the tones at step 264 and the receiver receives the tones at step 266. Alternatively, or in combination, the responder may be commanded to transmit the 23- tone **test** (^) to the master for analysis of the uplink path **audio** (^) quality. The responder then processes bins and prepares results at step 268, sending the result at step 270 to the master which receives them at step 272. The responder then proceeds to a wait for command state 256. Upon receipt of results of step 272, the master sends the results to the **test** (^) processor at step 274 after which it is placed in a done with command state 276.

Fig. 12 shows a flowchart for the network access **test.** (^) After start block 280, a call is placed to the mobile phone at step 282 after which call back instructions are sent at step 284. The system then hangs up and waits for a call at step 286, and is optionally subject to a time out 288. If the call is placed, the call is then accepted at step 290, where upon a request for the current location is made at step 292. A request for the oldest unsent is unsuccessful call details step 294 is made. At decision block 296, if the system has not received all unsent data, the system loops to yet again request the oldest unsent unsuccessful call detail step 294. If all unsent data has been received as determined at decision block 296, decision block 298 determines whether more call attempts are necessary. If not, the program flows to a done state 300, whereas if more call attempts are required the program flows to the hang up and wait for call state 286.

Fig. 13 shows a flowchart for an **audio** (^) quality **test.** (^) From start block 3 10, a call is placed to the mobile phone at step 312, upon which a request is made for the current location in step 314 as determined by the responder. Thereafter, a 23- tone **test** (^) is conducted at step 316. Alternatively, or in combination, the responder may be commanded to transmit the 23-tone **test** (^) to the master for analysis of the uplink path **audio** (^) quality.

Decision block 318 determines if the loop is done. If the loop is not done, another call to the mobile phone at step 312 is made. If the loop 318 is done, the system hangs up at step 320, and is placed in a done state 322. With regard to tone tests, such as the 23-tone **test,** (^) the system may be full duplex, half duplex or simplex.

Fig. 14 shows a flowchart for an unsuccessful completion **test.** (^) From start block 330, a call is placed to the mobile phone at step 332. After a request for the current location in step 334, the results are logged in the master at step 336. Thereafter, the system hangs up at step 338. As determined by decision block 340, if the loop is not done, the system loops back to the call mobile phone step 332, whereas if the loop 340 is done the system goes to a done state 342.

Fig. 15 shows a flowchart for a dropped call **test.** (^) From the start block 350, a call is placed to the mobile phone in step 352. The results are logged in the master at step 354.

10. The method of claim I for testing a wireless service provider network wherein the testing includes spectrum analysis.

11. The method of claim 1 for testing a wireless service provider network further including collection and transmission of information regarding global positioning.

12. The method of claim I I for testing a wireless service provider network wherein the global positioning information includes position.

13. The method of claim I I for testing a wireless service provider network wherein the global positioning information includes the time as provided by the global positioning system.

14. The method of claim I I for testing a wireless service provider network wherein the velocity of the mobile responder is detennined.

15. The method of claim I for testing a wireless service provider network wherein the transmission of infon-nation indicative of the parameters is performed in a call initiated by the master to the responder.

16. The method of claim I for testing a wireless service provider network wherein the step of transmitting information indicative of the parameters is performed in-a call initiated by the responder to the master.

17. The method of claim I for testing a wireless service provider network further including the step of analyzing the information transmitted to the master.

18. The method of claim 1 for testing a wireless service provider ftirther including the step of displaying the information provided from the responders to the master.

19. The method of claim I for testing a wireless service provider network ftu-ther including the step of archiving data supplied to the master in real time.

s 20. The method of claim I for testing a wireless service provider network further including the step of displaying information regarding the network in real time.

21. The method of claim I for testing a wireless service provider network further including the step of displaying geological information systems data in real time.

22. The method of claim I for testing a wireless service provider network further including the step of collecting data regarding calls not received.

is 23. A method for testing communication between a first wireless communication device and a second wireless communication device over a wireless service provider network, comprising the steps of- first, initiating a call from a master to a first responder including the first wireless communication device, second, initiating a call from the first wireless communication device to the second wireless communication device in a second responder over the wireless service provider network, monitoring parameters of the call, and communicating to the master information regarding the call between the first wireless communication device and the second wireless communication device.